CLAIMS

What is claimed is:

1. A light emitting diode comprising:

(a) a diamond substrate;

(b) a first aluminum gallium nitride layer above said diamond substrate having same conductivity type as said substrate;

(c) a quantum well structure on said first aluminum gallium nitride layer formed of a plurality of repeating sets of alternating layers selected from the group consisting of GaN, $In_xGa_{1-x}N$, where $0 < x < 1$, and $Al_xIn_yGa_{1-x-y}N$, where $0 < x < 1$ and $0 < y < 1$ and $0 < x+y < 1$;

(d) a second aluminum gallium nitride layer on said quantum well structure having conductivity type opposite of said first aluminum gallium nitride layer;

(e) a contact structure on said second aluminum gallium nitride layer having conductivity type opposite of said substrate and said first aluminum gallium nitride layer;

(f) an ohmic contact to said diamond substrate; and

(g) an ohmic contact to said contact structure.

2. The light emitting diode of claim 1 wherein said diamond substrate is a single crystal or CVD deposited diamond.

3. The light emitting diode of claim 1 wherein said diamond substrate is a semiconducting substrate for desired absorption in the Blue and ultraviolet wavelengths.

4. The light emitting diode of claim 1 wherein said diamond substrate and said first aluminum gallium nitride layer have p-type conductivity.

5. The light emitting diode of claim 1 further comprising:

(h) a buffer layer on said diamond substrate for providing a crystal and electronic transition between said substrate and the remainder of said LED.

6. The light emitting diode of claim 5 wherein said buffer layer is $Al_xGa_{1-x}N$ where $1 \geq x \geq 0$.

7. The light emitting diode of claim 5 further comprising:

(i) a plurality of graded layers of $Al_xGa_{1-x}N$ where $1 > x > 0$ on said quantum well or bulk active layer and said buffer layer for reducing propagation of defects that tend to originate in said substrate.

8. The light emitting diode of claim 1 wherein said quantum well comprises a plurality of periods of alternating layers of GaN and $In_xGa_{1-x}N$ where $0 < x < 1$.

9. The light emitting diode of claim 1 wherein said quantum well includes between 2 and 20 periods of said alternating layers.

10. The light emitting diode of claim 8 wherein said $In_xGa_{1-x}N$ layers and said GaN layers are doped n-type.

11. The light emitting diode of claim 1 wherein said quantum well comprises a plurality of periods of alternating layers of $In_xGa_{1-x}N$ and $In_yGa_{1-y}N$, where $0 < x < 1$ and $0 < y < 1$ and x does not equal y.

12. The light emitting diode of claim 1 wherein said quantum well is formed of a plurality of periods of alternating layers of $Al_xGa_{1-x}N$ and $Al_yGa_{1-y}N$, where $0 < x < 1$ and $0 < y < 1$ and x does not equal y.

13. The light emitting diode of claim 1 wherein said second aluminum gallium nitride layer comprises a doped portion and an undoped portion for protecting said multiple quantum well from undesired doping.

14. The light emitting diode of claim 13 wherein said doped portion of said first aluminum gallium nitride layer is immediately adjacent to said quantum well and said undoped portion of said second aluminum gallium nitride layer is immediately adjacent to said multiple quantum well.

15. The light emitting diode of claim 1 wherein said multiple quantum well comprises a plurality of repetitions of a basic structure formed of a layer of $In_xGa_{1-x}N$, where $0 < x < 1$ and a layer of GaN.

16. The light emitting diode of claim 15 wherein at least one of said $In_xGa_{1-x}N$ layers is undoped.

17. The light emitting diode of claim 1 wherein said multiple quantum well comprises alternating layers of $In_xGa_{1-x}N$ and $In_yGa_{1-y}N$, where $1 > x > 0$ and $1 > y > 0$ and where x does not equal y.

18. The light emitting diode of claim 17 wherein at least one of said $In_xGa_{1-x}N$ and said $In_yGa_{1-y}N$ layers is undoped.

19. The light emitting diode of claim 1 wherein said multiple quantum well comprises alternating layers of $In_xGa_{1-x}N$ where $0<x<1$ and $Al_xIn_yGa_{1-x-y}N$, where $0<x<1$ and $0<y<1$ and $0<x+y<1$.

20. The light emitting diode of claim 19 wherein at least one of said $In_xGa_{1-x}N$ layers is undoped.

21. The light emitting diode of claim 15 wherein x is equal to about 0.15 in said alternating $In_xGa_{1-x}N$ layers.

22. The light emitting diode of claim 15 wherein at least one of said GaN layers in said multiple quantum well comprises a first portion of doped GaN and a second portion of undoped GaN with said undoped portion being immediately adjacent to at least one of said undoped $In_xGa_{1-x}N$ layers.

23. The light emitting diode of claim 1 wherein said multiple quantum well includes at least three quantum wells.

24. The light emitting diode of claim 1 wherein said multiple quantum well includes at least five quantum wells.

25. The light emitting diode of claim 1 wherein said multiple quantum well includes at least seven quantum wells.

26. The light emitting diode of claim 23 wherein a thickness of each said well is no more than about 100 Angstroms.

27. The light emitting diode of claim 23 wherein a thickness of each said well is about 50 Angstroms

28. The light emitting diode of claim 15 wherein $0<x<0.3$ in said $In_xGa_{1-x}N$ layers in said multiple quantum well.

29. The light emitting diode of claim 15 wherein $0<x<0.15$ in said $In_xGa_{1-x}N$ layers in said multiple quantum well.

30. The light emitting diode of claim 15 wherein x is such that said multiple quantum well produces a photon in ultraviolet or blue region of an electromagnetic spectrum.

31. The light emitting diode of claim 17 wherein x and y are such that said multiple quantum well produces a photon in ultraviolet or blue region of an electromagnetic spectrum.

32. The light emitting diode of claim 18 wherein x is such that said multiple quantum well produces a photon in ultraviolet or blue region of an electromagnetic spectrum.

33. The light emitting diode of claim 1 wherein said multiple quantum well emits a peak wavelength between about 370 nanometers and 470 nanometers.

34. The light emitting diode of claim 1 wherein said contact structure comprises a n-type GaN contact layer.

35. The light emitting diode of claim 34 wherein said contact structure further comprises:

(h) at least one layer of $Al_xGa_{1-x}N$ where $0<x<1$ adjacent to said n-type GaN contact layer and opposite to said ohmic contact with respect to said n-type contact layer.

36. The light emitting diode of claim 34 wherein said contact structure comprises an undoped $Al_xGa_{1-x}N$ layer, where $0<x<1$, on said third GaN layer and a n-type $Al_xGa_{1-x}N$ layer, where $0.1>x>1$, on said undoped $Al_xGa_{1-x}N$ layer.

37. The light emitting diode of claim 1 wherein said third layer of GaN is doped with magnesium to produce a p-type conductivity.

38. The light emitting diode of claim 1 wherein said third layer of GaN is doped with silicon to produce an n-type conductivity.

39. The light emitting diode of claim 4 wherein said contact structure comprises a n-type layer of $Al_xGa_{1-x}N$, where $0<x<1$.

40. The light emitting diode of claim 4 wherein said contact structure comprises a p-type contact to diamond substrate.

41. The light emitting diode of claim 4 wherein said contact structure comprises a n-type Group III nitrides.

42. The light emitting diode of claim 1 wherein said multiple quantum well emits in ultraviolet and blue portion of an electromagnetic spectrum further comprising:

(h) a phosphor responsive to ultraviolet radiation that produces a visible photon in response to an ultraviolet photon emitted by said multiple quantum well.

43. A method of fabricating a light emitting diode, comprising the steps of:

(a) growing a first aluminum gallium nitride layer on a diamond substrate having conductivity type of said substrate;

(b) growing a quantum well structure of active layer on said first aluminum gallium nitride layer comprising a plurality of repeating sets ("periods") of alternating layers selected from the group consisting of GaN, $In_xGa_{1-x}N$ where $0<x<1$, and $Al_xIn_yGa_{1-x-y}N$ where $x+y<1$;

(c) growing a second aluminum gallium nitride layer on said quantum well structure having conductivity type of said first aluminum gallium nitride layer;

(d) growing a contact structure on said second aluminum gallium niride layer having conductivity type opposite of said diamond substrate and forming an ohmic contact to said diamond substrate; and

(e) forming an ohmic contact to said contact structure.

44. The method of fabricating a light emitting diode of claim 43 wherein said layers formed of Group III nitrides are grown using metal-organic chemical vapor deposition.

45. The method of fabricating a light emitting diode of claim 43 further comprising the steps of:

(f) growing an $Al_xGa_{1-x}N$ buffer layer on said diamond substrate to a thickness of about 3,000 Angstroms at a temperature of about 1,000° C; and

(g) thereafter growing said first aluminum gallium nitride layer on said $Al_xGa_{1-x}N$ buffer layer.

46. The method of fabricating a light emitting diode of claim 45 further comprising the step of:

(h) growing graded layers of $Al_xGa_{1-x}N$ on said buffer layer over a temperature range of 200-1000° C so as to reduce defect migration to said active layer.

47. The method of fabricating a light emitting diode of claim 46 further comprising the step of:

(i) growing said graded layers of $Al_xGa_{1-x}N$ on said buffer layer at a temperature of about 700° C.

48. The method of fabricating a light emitting diode of claim 43 further comprising the steps of:

(f) growing the first aluminum gallium nitride layer on said substrate to a thickness of about 30,000 Angstroms at temperature of about 1,090° C such that a

lateral growth rate of said first aluminum gallium nitride layer is greater than its vertical growth rate;

(g) reducing temperature to about 1,030° C for a period of time as said aluminum gallium nitride layer grows and thereafter to about 790° C for a period of time; and

(h) reducing temperature gradually during final phase of growth of said aluminum gallium nitride layer to about 770° C in order to prepare for growth of said $In_xGa_{1-x}N$ multiple quantum well.

49. The method of fabricating a light emitting diode of claim 43 wherein the step of fabricating said quantum wells comprises growing alternating layers of $In_xGa_{1-x}N$ and GaN and doping both alternating layers with silicon to produce a n-type conductivity.

50. The method of fabricating a light emitting diode of claim 43 further comprising the step of growing undoped layers of $In_xGa_{1-x}N$ and GaN.

51. The method of fabricating a light emitting diode of claim 43 further comprising the step of forming between two and ten said quantum wells of alternating layers.

52. The method of fabricating a light emitting diode of claim 43 further comprising the step of forming said second GaN layer with a first portion having a thickness of about 250 Angstroms at a temperature of about 820° C and doping the second GaN layer with silicon.

53. The method of fabricating a light emitting diode of claim 43 further comprising the steps of forming said second GaN layer with a second, narrower portion at a temperature of about 820° C and without doping to thereby separate an undoped $In_xGa_{1-x}N$ layer in said multiple quantum well from a doped portion of said second

GaN layer.

54. The method of fabricating a light emitting diode of claim 43 wherein the step of fabricating said multiple quantum well comprises the steps of: growing an undoped layer of $In_xGa_{1-x}N$ to a thickness of about 50 Angstroms at a first temperature of about 770° C; growing an undoped layer of GaN on said undoped layer of $In_xGa_{1-x}N$ to a thickness of about 50 Angstroms at a temperature of about 770° C; growing another layer of GaN at a temperature of about 820° C., and doping said layer with silicon to help improve the conductivity of said GaN; growing another undoped layer of GaN at a temperature of about 770° C.; extending said undoped GaN layer by growing it at a second temperature higher than about 770° C., said second temperature being high enough to promote higher quality growth of said GaN, but low enough to avoid degrading said nearby, non-adjacent $In_xGa_{1-x}N$ well; and growing a final portion of said undoped layer of GaN to a thickness of about 35 Angstroms at a temperature of about 840° C.

55. The method of fabricating a light emitting diode of claim 54 comprising repeating the steps of fabricating said multiple quantum well at least three times in order to fabricate three quantum wells.

56. The method of fabricating a light emitting diode of claim 54 comprising repeating the steps of fabricating said multiple quantum well at least five times in order to fabricate five quantum wells.

57. The method of fabricating a light emitting diode of claim 54 comprising repeating the steps of fabricating said multiple quantum well at least seven times in order to fabricate seven quantum wells.

58. The method of fabricating a light emitting diode of claim 54 wherein fabricating said multiple quantum well comprises growing a final well of $In_xGa_{1-x}N$ at a temperature of about 770° C to a thickness of about 50 Angstroms and growing a final layer of undoped GaN at a temperature of about 770° C to a thickness of about 35 Angstroms.

59. The method of fabricating a light emitting diode of claim 54 further comprising the step of growing said third GaN layer on said multiple quantum well at a temperature of about 820° to a thickness of about 100 Angstroms.

60. The method of fabricating a light emitting diode of claim 59 further comprising the step of doping said third GaN layer with magnesium to produce p-type conductivity.

61. The method of fabricating a light emitting diode of claim 59 further comprising the step of doping said third GaN layer with silicon to produce n-type conductivity.

62. The method of fabricating a light emitting diode of claim 43 wherein the step of fabricating said contact structure comprises the steps of: growing a first undoped $Al_xGa_{1-x}N$ layer at a temperature of about 890° C to a thickness of about 50 Angstroms; growing a silicon doped layer of $Al_xGa_{1-x}N$ with n-type conductivity at a temperature of about 890° C. to a thickness of about 100 Angstroms; and growing a GaN contact layer doped with silicon to have a n-type conductivity at a temperature of about 980° C to a thickness of about 2000 Angstroms.

63. The method of fabricating a light emitting diode of claim 62 wherein said n-type layers of said contact structure are fabricated using materials selected from the group

of $Al_xGa_{1-x}N$, $In_xGa_{1-x}N$ and GaN, where $0<x<1$, as substitutes for said doped layer of $Al_xGa_{1-x}N$ and said doped layer of GaN.